Arizona Department of Transportation

Bridge Group

BRIDGE PRACTICE GUIDELINES

SECTION 3- LOADS AND LOAD FACTORS

SCOPE

This section contains guidelines to supplement provisions of Section 3 of the AASHTO Specifications which specifies minimum requirements for loads and forces, the limits of their application, load factors, and load combinations used for the design of new bridges. The load provisions may also be applied to the structural evaluation and modification of existing bridges.

In accordance with the applicable provisions of the AASHTO Specifications, the Service Load Design method (Allowable Stress Design) shall be used for the design of all members except columns, sound barrier walls and bridge railings. Columns and sound barrier walls shall be designed by the Strength Design method (Load Factor Design). Bridge railing design for new bridges shall be based on the AASHTO LRFD Bridge Design Specifications.

For load applications and distributions for specific bridge types, refer to the following sections.

TYPES OF LOADS

Loads shall be as specified in **Section 3** of **AASHTO** except as clarified or modified in these guidelines. **AASHTO** loading specifications shall be the minimum design criteria used for all bridges.

Dead Loads (AASHTO 3.3)

The dead load shall consist of the weight of entire structure, including the roadways, curbs, sidewalks, railing. In addition to the structure dead loads, superimposed dead loads such as pipes, conduits, cables, stay-in-place forms and any other immovable appurtenances should be included in the design.

SHORTENING

Dead load should include the elastic effects of prestressing (pre or post-tensioned) after losses. The long-term effects of shrinkage and creep on indeterminate reinforced concrete structures may be ignored, on the assumption that forces produced by these processes will be relieved by the same processes.

BOX GIRDER DECK FORMS

Where deck forms are not required to be removed, an allowance of 5-10 lb/ft^2 for form dead load shall be included.

DIFFERENTIAL SETTLEMENT (AASHTO 3.3.2.1)

Differential settlement shall be considered in the design when indicated in the Geotechnical Report. The Geotechnical Report should provide the magnitude of differential settlement to be use in the design. Differential settlement shall be considered the same as temperature and shrinkage forces and included in **Group IV**, **V** and **VI** load combinations.

FUTURE WEARING SURFACE (AASHTO 3.3.3)

All new structures shall be designed to carry an additional dead load of 25 pounds per square foot from curb to curb of roadway to allow for a future wearing surface. This load is in addition to any wearing surface, which may be applied at the time of construction. The weight of the future wearing surface shall be excluded from the dead load for deflection calculations.

WEARING SURFACE (AASHTO 3.3.5)

The top ½" of the deck shall be considered as a wearing surface. The weight of the ½" wearing surface shall be included in the dead load but the ½" shall not be included in the depth of the structural section for all strength calculations including the deck, superstructure and the pier cap, where appropriate.

Live Load & Impact (AASHTO 3.4 - 3.8, 3.11, 3.12)

The design live load shall consist of the appropriate truck or lane loading in accordance with **AASHTO 3.7.3**. As a minimum, all bridges in Arizona will be designed for HS20-44 loading. In addition, bridges supporting Interstate highways, or other highways which carry heavy truck traffic, will be designed for Alternative Military Loading (**AASHTO 3.7.4**).

The lane loading or standard truck shall be assumed to occupy a width of 10 feet. These loads shall be placed in 12-foot wide design traffic lanes, spaced across the entire bridge roadway width measuring between curbs. Fractional parts of design lanes shall not be used, but roadway width from 20 to 24 feet shall have two design lanes each equal to one-half the roadway width. The traffic lanes shall be replaced in such numbers and positions on the roadway, and the loads shall be placed in such positions within their individual traffic lanes, so as to produce the maximum stress in the member under consideration. Where maximum stresses are produced in any member by loading with three or more traffic lanes simultaneously, the live load may be reduced by a probability factor as covered in **AASHTO 3.12**. This would apply to members such as transverse floor beams, truss, and two-girder bridges, pier caps, pier columns or any member that has been loaded more than two traffic lanes. This does not apply to deck slab or longitudinal beams designed for fractional wheel loads since less than three traffic lanes will produce the maximum stress. Generally, a reduction factor will be applied in the substructure design for multiple loadings.

An impact factor shall be applied to the live load in accordance with **AASHTO 3.8**. The live load stresses for the superstructure members resulting from the truck or lane loading on the superstructure, shall be increased by an allowance for dynamic, vibratory and impact effect. Impact should be included as part of the loads transferred from the superstructure to the substructure, but shall not be included in loads transferred to the footing nor to those parts of piles or columns that are below ground (**AASHTO 3.8.1-3.8.2**).

Longitudinal Forces (AASHTO 3.9)

Provision shall be made for the effect of a longitudinal force of 5 percent of the live load in all lanes carrying traffic headed in the same direction without impact.

Centrifugal Forces (AASHTO 3.10)

Centrifugal forces are included in all groups which contain vehicular live load. They act 6 feet above the roadway surface and are significant when curve radii are small or columns are long. They are radial forces induced by moving trucks. See **AASHTO 3.10.1, Equation (3-2)** for force equation.

Wind Loads (AASHTO 3.15)

Wind loads shall be applied according to Section 3.15 of the Standard Specifications.

Thermal Forces (AASHTO 3.16)

Thermal movement and forces shall be based on the following mean temperatures and temperature ranges.

		Concrete		**Steel**	
Elevation (ft)	**Mean (^oF)**	**Rise (^oF)**	**Fall (^oF)**	**Rise (^oF)**	**Fall (^oF)**
Up to 3000	70	30	40	60	60
3000 - 6000	60	30	40	60	60
Over 6000	50	35	45	70	80

The effects of differential temperature between the top slab and bottom slab of concrete box girder bridges is normally not considered. However, when approval is obtained for structures which warrant such consideration, the following temperature ranges should be used.

DL + Diff Temp	Delta = 18 degrees
DL + LL + I + Diff Temp	Delta = 9 degrees

Stream Forces (AASHTO 3.18.1)

A Bridge Hydraulics Report as outlined in Section 2 shall be produced by Roadway Drainage Section or a consultant, when appropriate, for all stream crossings. The designer should review the Bridge Hydraulics Report for a full understanding of waterway considerations. The report should contain as a minimum the following information for both the critical flow and superflood conditions.

- High water elevation
- Mean Velocity
- Scour Elevations (General and Local)
- Angle of attack
- Required bank protection
- Special drainage considerations

For design for the most critical flow and the superflood condition, the following criteria shall be used unless more severe criteria are recommended in the Bridge Hydraulics Report.

- Design calculations of stream forces on piers over natural water courses shall assume a 2 foot increase in pier width per side due to blockage by debris with a shape factor k = 1.40 for the first 12 feet of depth of flow. For flows with depths greater than 12 feet, only the top 12 feet shall be assumed blocked by debris with lower sections using the actual pier width and a shape factor in accordance with AASHTO. For uncased drilled shafts, a 20% increase in diameter should be assumed to account for possible oversizing of the hole and any irregular shape. The force distribution on the pier shall be assumed to vary linearly from the value at the water surface to zero at the bottom of the scour hole as described in AASHTO.

- When the clear distance between columns or shafts is 16 feet or greater, each column or shaft shall be treated as an independent unit for stream forces and debris. When the clear distance is less than 16 feet the greater of the two following criteria shall be used:
  1) Each column or shaft acting as an independent unit or 2) All columns or shafts acting as one totally clogged unit.

- The mean main channel velocity for the appropriate flow condition shall be used in calculating the stream forces. The water surface elevation shall be the high water elevation for the appropriate flow condition. A minimum angle of attack of 15 degrees shall be assumed.

- Scour may be categorized into two types: general and local. General scour is the permanent loss of soil due to degradation or mining while local scour is the temporary loss of soil during a peak flow. Local scour may consist of two types: contraction scour and local pier or abutment scour. Contraction scour occurs uniformly across the bridge opening when the waterway opening of the bridge causes a constriction in the stream width. Local pier and abutment scour occurs locally at substructure units due to the turbulence caused by the presence of the substructure unit.

- Bridge foundation units outside the highwater prism need not be designed for scour or stream forces. Spread footing bearing elevations shall be minimum 5 ft. below the channel thalweg elevation. Tip of drilled shaft elevations shall be minimum 20 ft. below the channel thalweg elevation unless in rock sockets.

- Bridges over natural watercourses shall be investigated for four different streambed ground lines. Refer to Figure 1 for an illustration of these cases.

1. Case 1 is the as-constructed stream cross section. For this case, the bridge shall be designed to withstand the forces from the **AASHTO Groups I** to **VII** load combinations.

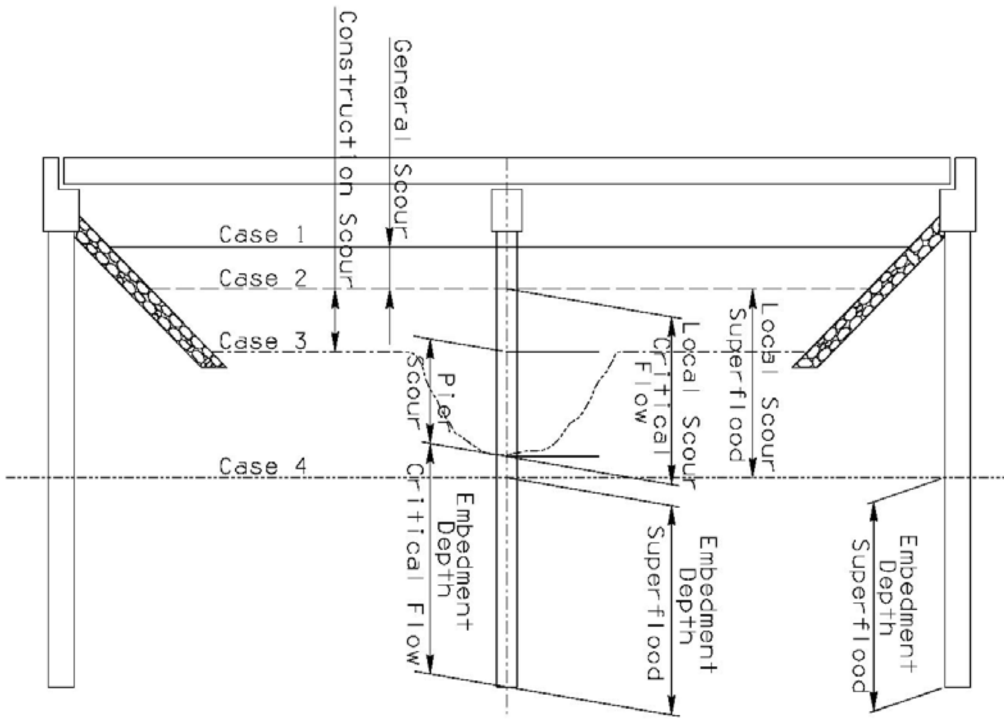
2. Case 2 represents the long-term dry streambed cross section (i.e. the as-constructed stream cross section minus the depth of the general scour). For this case, the bridge shall be designed to withstand the same forces as for case 1. Bridges need only be designed for Seismic Forces for the case of general scour. The requirements contained in **AASHTO 4.4.5.2** need not be met.

3. Case 3 represents the streambed cross section condition for the most critical design flow. Abutment protection is designed to withstand this event and abutments may be assumed to be protected from scour for this condition. Piers will experience the full general and critical flow local scour. For this case, the bridge shall be designed to withstand the forces from the **AASHTO Groups I** to **VI** load combinations.

4. Case 4 represents the streambed cross section conditions for the superflood condition. For this case, all bank protection and approach embankments are assumed to have failed.

Abutments and piers should be designed for the superflood scour assuming all substructure units have experienced the maximum scour simultaneously. For this case, the bridge shall be designed to withstand the following forces: **DL + SF + 0.5W**. For members designed using the **WSD** Method an allowable overstress of 140% shall be used. For members designed using the **LFD** Method a gamma factor of 1.25 shall be used.

FIGURE 1
GROUNDLINE VARIATIONS DUE TO SCOUR



Lateral Earth Pressure (AASHTO 3.20.1)

For backfills compacted in conformance with the **AASHTO Standard Specifications**, active pressure for unrestrained walls should be calculated using an internal angle of friction of 34 degrees unless recommended otherwise in the Geotechnical Report.

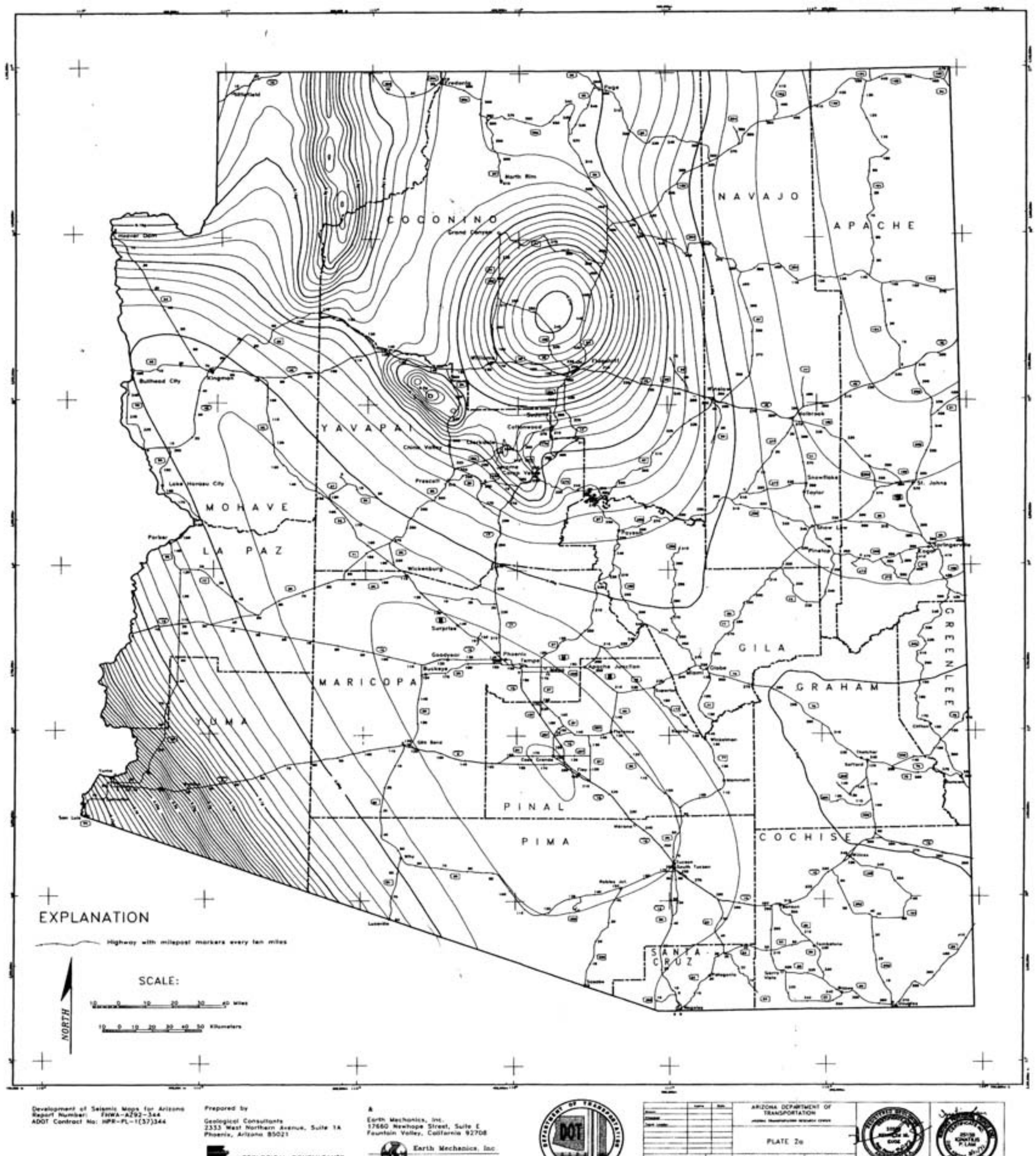
Earthquakes (AASHTO 3.21)

The Standard Specifications for Highway Bridges shall be used for the seismic design of all new structures. However, the **Seismic Acceleration Map**, Figure 1-5, contained in **AASHTO Division I-A Seismic Design** shall not be used to determine the Acceleration Coefficient A. A seismic map for Arizona developed through the Arizona Transportation Research Center is contained in **Report Number FHWA-AZ 92-344**. This map provides horizontal accelerations in rock with 90% probability of not being exceeded in 50 years considering the effects of local faults. This map shall be used for all designs. A reduced copy of this map is included in Fig. 2 for information purposes. A full size map may be obtained by contacting Bridge Technical Section at (602) 712-7910 and should be used in actual designs.

All new or widened bridge designs shall consider some form of vertical restraints. Vertical restraints shall be provided for all expansion seat abutments except for multi-span continuous box girder bridges with integral piers. Vertical restraints shall be provided between all substructure and superstructure units for steel and precast prestressed girder bridges. When required, the vertical restraints shall be designed for a minimum force equal to 10 percent of the contributing dead load unless the Standard Specifications, Division I-A Seismic Design require a higher value.

For Seismic Performance Category A Bridges, horizontal restrainers for hinges shall be designed for a force equal to 0.25 x DL of the smaller of the two frames with the column shears due to EQ deducted. For Seismic Performance Category B, C and D bridges, horizontal restrainers for hinges shall be designed in accordance with the Standard Specifications, Division I-A Seismic Design.

FIGURE 2
MAP OF HORIZONTAL ACCELERATION AT BEDROCK FOR ARIZONA



MAP OF HORIZONTAL ACCELERATION AT BEDROCK FOR ARIZONA
with 90 Percent Probability of Non-Exceedance in 50 Years
By
Ignatius Po Lam, Bruce A. Schell and Kenneth M. Euge, 1992

DISTRIBUTION OF LOADS

Loads shall be distributed as specified in **Section 3** of **AASHTO** except as clarified or modified in these guidelines.

Truck wheel loads are delivered to a flexible support through compressible tires, which make it very difficult to define the area of the bridge deck significantly influenced. Computerized grid systems and finite element programs can come close to reality, but they are complicated to apply and are limited by mesh or element size and by the accuracy with which the mechanical properties of the composite materials can be modeled. These two- or three dimensional problems are reduced to one dimension through various empirical distribution factors given in the **AASHTO Standard Specifications**.

These distribution factors have been derived from research involving physical testing and/or computerized parameter studies. In order to simplify the design procedure, the number of variables was reduced to a minimum consistent with safety and reasonable economy, according to the judgment of the AASHTO Subcommittee on Bridges and Structures. The factor S/5.5, so developed, has been used for many years to determine the portion of a wheel load to be supported by steel or prestressed concrete girders under a concrete slab. Other variables, such as span aspect ratio, skew angle and relative stiffness between stringer and slab, are not considered except for occasional special bridges. The conservatism of this approach may account for some of the reserve strength regularly observed when redundant girder bridges are load tested. Similarly, concrete slab spans and slabs on girders will invariably support much more load than predicted by empirical analysis.

Treatment of wheel load distribution to the various bridge components in the **AASHTO Standard Specifications** is as follows:

Longitudinal Beams (Girders)

Distribution factors given in the **AASHTO 3.23.1, 3.23.2 and Table 3.23.1** are used almost exclusively. Occasionally, special conditions will justify the use of a discrete element grid and plate solution.

For simplicity of calculation and because there is no significant difference, the distribution factor for moment is used also for shear.

Composite dead loads (such as curbs, barriers and wearing surfaces) are distributed equally to all stringers except for extraordinary conditions of deck width or ratio of overhang to beam spacing. Live load is distributed to all types of outside beams assuming the deck to act as a simple cantilever span supported by the outside and the first inside stringer.

Concrete Box Girders AASHTO 3.23.2.3.2.2)

In calculating the number of lanes of live load on the superstructure, the entire cross section of the superstructure shall be considered as one unit with the number of lanes of live load equal to the out-to-out width of the deck divided by 14. Do not reduce this number for multiple lanes as specified in **AASHTO 3.12.1** nor round to a whole number as specified in **AASHTO 3.6.3**.

Transverse Beam (Floorbeams, AASHTO 3.23.3)

For the few cases where floorbeams have been used without stringers on highway bridges, it has appeared proper to calculate reaction assuming the deck slab to act as a continuous beam supported by the floorbeams. No transverse distribution of wheel loads is allowed unless a sophisticated analysis is used.

Multi-beam Decks(AASHTO 3.23.4.1)

Refer to Bridge Practice Guidelines, Section 5, Page 23.

Concrete Slabs – Reinforced Perpendicular to Traffic (Slab on Stringer)

For this component, distribution of wheel load is built into a formula for moment. ADOT designs are standardized according to the requirements of the current **AASHTO 3.24.3.1**. Span length of slabs on prestressed concrete stringers may be taken as the clear distance between flanges.

Concrete Slabs – Reinforced Parallel to Traffic (Slab Spans)

Loads are distributed according to **AASHTO 3.24.3.2**. The approximate formula for moment is not used.

For skews up to 30 degrees, main reinforcing is parallel to traffic and no additional edge beam strength is needed for usual railing conditions. For 30 degree skew and greater, reinforcing is perpendicular to the bents and edge beam strength is provided and reinforced parallel to traffic.

Concrete Slabs – Reinforced Both Ways (AASHTO 3.24.6)

Divide the load between transverse and longitudinal spans according to the formulae for slabs supported on four sides. Use the appropriate load distribution in each direction.

Timber Flooring, Composite Wood – Concrete Members and Glued Laminated Timber Decks (AASHTO 3.25 & 3.26)

Timber is not normally used in bridge construction in Arizona.

Steel Gird Floors (AASHTO 3.26)

Follow the Specifications Closely. This type of construction is seldom used in Arizona.

Spread Box Girders (AASHTO 3.28)

Follow the Specifications Closely. This type of construction is seldom used in Arizona.

Live Load Distribution (AASHTO 3.6.3. and 3.12.1)

In designing the superstructure, the live load distribution factors shall not be reduced for multiple lanes as specified in **AASHTO 3.12.1** or rounded to a whole number as specified in **AASHTO 3.6.3**. These two reductions apply to substructure design only.

Horizontal loads on the superstructure distribute to the substructure according to a complicated interaction of bearing and bent stiffness. For continuous steel units, the following method will usually be sufficiently accurate:

- Apply transverse loads times the average adjacent span length.
- Apply longitudinal loads times the unit length to the fixed bent according to their relative stiffness.
- Calculate deformations due to temperature changes given in this guideline and convert to forces according to the stiffness of the fixed bent.
- Centrifugal force is based on the truck load reaction to each bent.

Friction in expansion bearings can usually be ignored but, if its consideration is desirable, the maximum longitudinal force may be taken as 0.10 times the dead load reaction for rocker shoes and PTFE sliding bearings.

For prestressed concrete beam spans and units on elastomeric bearings, fixity is superficial and all bearings are approximately the same stiffness. It will usually be sufficiently accurate to distribute horizontal loads in the following manner:

- Apply transverse and longitudinal loads times the average adjacent span length. The concentrated live load for longitudinal force would be located at each bent.
- Forces due to temperature deformations may be ignored.
- Centrifugal force is based on the truck load reaction to each bent.

If temperature consideration is desirable, deformations may be based on the temperature changes given in this guideline.

LOAD COMBINATIONS

Group numbers represent various combinations of loads and forces which may act on a structure. Group loading combinations for both Load Factor and Service Load Design are defined by **AASHTO 3.22.1** and **Table 3.22.1A**. The loads and forces in each group shall taken as appropriate from **AASHTO 3.3** to **3.21**.

Structures may be analyzed for an overload that is selected by the owner. Size and configuration of the overload, loading combinations, and load distribution will be consistent with procedures defined in the permit policy. The load shall be applied in Group IB as defined in **AASHTO Table 3.22.1A**. For all loadings less than H 20, **Group IA** loading combination shall be used (**AASHTO 3.22.5**).